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## An Assessment of Groundwater Potential for Water Supply in Misau and Dambam Local Government Areas of Bauchi State, Nigeria

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### ABSTRACT

This study aimed at assessing groundwater potential in Misau and Dambam areas of Bauchi State, Nigeria. Vertical Electrical Sounding (VES) survey was also conducted to carry out the study. Five thematic maps were generated for weighted overlay. Descriptive statistics were used to analysed data on water supply situation, aquifer parameters were analysed using a standard table where porosity and permeability were calculated. The VES data was analysed using ipi2win, thematic maps were produced through overlay analysis using the extension of ArcGIS 10.4. VES result reveals the existence of about three to four geologic layers in the study area which constitute the topsoil, weathered rock, weathered/fractured rock, fractured basement, and fresh basement rock. Nine out of the thirteen soundings conducted were found to be of sound in nature while the only non-promising aquifers were found in Jalam Kukadi, Hardawa PHC, Bada Koshi, Dambam A Bam. Five groundwater potential zones were determined which are very low 354 km<sup>2</sup> (15%), low 393 km<sup>2</sup> (15%), moderate 416 km<sup>2</sup> (20%), high 436 km<sup>2</sup> (25%), and very high 497 km<sup>2</sup> (25%). Drainage is the most critical factor affecting groundwater occurrence with 25% which is the highest followed by geology with 22%. It can be concluded that 50% of the study area was characterized under high, and very high groundwater potential. It is recommended that areas with poor groundwater potentials government and non-governmental organizations should provide an alternative source of water to aid them during periods of difficulties.

### INTRODUCTION

The quality of life is greatly influenced by water. Despite making up about 70% of the surface of the earth, humans can only use 0.3% of the water (Ahmed, 2014). The largest source of drinkable water among the various sources is groundwater. The water reserve found in the saturated area of the ground beneath the surface of the land is known as groundwater. When water seeps into the ground and descends due to gravity through the pore spaces between soil particles and rock cracks, it typically collects there. At some point, the water submerges to a depth where the rock and soil are saturated (United State Environmental Protection Agency, 2014). Only 3.4% of Nigeria's 94,185,000 hectare total land area is covered by fresh water resources, which is not enough to satisfy the country's population of over 199,728,050 million people (United Nations, 2019). Water supply systems are under pressure due to the rise in population, changes in lifestyle, and socioeconomic activities, which are thought to be contributing factors to the lack of water in Nigeria's rural and urban areas, including Misau and Dambam (Ayanshola & Salami, 2010). Groundwater development is receiving more attention as a result of the high water demand in various parts of the world. One of the alternative water sources that can be investigated to help alleviate the water shortage for domestic and agricultural uses in Misau and Dambam is groundwater. A vital hidden and replenishable resource is groundwater. Its distribution and occurrence are dependent on regional and local geology, hydrogeology,

and human activity types (Yusuf *et al.*, 2012).

According to Rilwanu (2014), to successfully explore groundwater in each environment, one must have a thorough understanding of the hydrological features of the region. Thus, groundwater exploration requires the use of a variety of geophysical and hydrogeological methods, including electrical resistivity, seismic, magnetic, electromagnetic, ground probing radar, pumping tests, and down-hole logging (Anomohanran, 2013a). For its investigation, the electrical resistivity method employs a variety of techniques, and the instrument used varies according to the type of technique employed (Anomohanran, 2013b). Around one billion people worldwide lack access to a sufficient supply of potable water, according to Jidauna *et al.*, (2013). Although water covers about 75% of the earth's surface, access to potable water that is safe for drinking and sanitation is a problem that affects all developing countries, according to the World Health Organization in 2006. (Isa & Olugbenga, 2015). In Nigeria, both government and individuals drill boreholes with little or no consideration for hydrogeology and its relationship with host rocks and lithological formation and this causes a serious lapse in groundwater development with a lot of abortive boreholes being drilled. Nigerian groundwater development is funded by 700 million dollars from the Africa Development Bank. The study of the earth through measurement at or close to its surface is known as a geophysical survey. The geophysical method is thought to be the most effective tool for groundwater exploration

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**Figure 1:** Water vendors queue to fetch Water from Electric Borehole as their Commodity at Gundari Misau

because it has been used extensively in geotechnical and geo-environmental research.

The rapid population increase in Misau and Dambam exalted greater water demand. The two local governments have no municipal water treatment plant and the main source of water that is used more often and frequently are electric boreholes, hand-dug boreholes, open wells that are very rare, and solar boreholes. However, the electric boreholes are present only within the vicinity of Misau there are two one is a 450,000-liter storage capacity and the other is a 300,000-liter storage capacity, constructed in 1980, and 1992 respectively. Dambam has only one tank which is a 300,000-liter storage capacity, constructed in 1992 according to Misau Water Board Records Book. Despite the effort of the government and supporting agencies towards tackling the water crisis in rural and urban areas, rural and remote areas of Misau and Dambam are still suffering from water shortage due increase in population that is so rapid and exalting pressure on the insufficient resources in the study area.

The study area is water stressed because the borehole yield is 98.67m<sup>3</sup>, Wali and Modibbo (2015). The need for identification and exploration of the sedimentary and basement complex aquifer in Misau and Dambam is vital to identify the zones of Groundwater potential for reliable water supply. However, the drilling of unproductive boreholes, Tube wells, and Hand-dug wells which brought water scarcity over the years has been a matter of concern to the inhabitants of the study area. The study aims to assess groundwater potential for water supply in Misau and Dambam areas of Bauchi State for water supply development.

### LITERATURE REVIEW

In Nigeria, suitable machinery for the effective and sustainable management of groundwater resources is not yet widely available especially in rural and remote areas this is because the authorities have put up institutions for the purpose of alleviating water deficiencies State Ministry of Water Resources, but at the same time set up rival agencies to carry out very overlapping functions

e.g Rural Water Supply and Sanitation Agencies, (Nwankwoala, 2008). According to Ajayi (2006), the major obstacles for sound groundwater management include: absence of or ineffective legal/institutional and regulatory framework, poor maintenance culture, poor technical and institutional capacity, lack of coordination, multiple programs, lack of data and information for planning, shortage of well-trained/committed manpower with appropriate local technology, irregular recruitment and limited manpower occasioned by the civil- service structure and the over-bearing bureaucratic control by supervising ministries, lack of professional input on water programs and projects, absence of professionalism due to politicization, career

stagnation and the lure of private practice, lack of community participation and inadequate revenue generation by water agencies, inadequate funding as shown by poor budget allocations,

Abdullahi, Ahmad and Sunusi (2017) conducted a geoelectrical investigation to generate a groundwater potential map at the Yelwa Campus of Abubakar Tafawa Balewa University (ATBU), Bauchi, Nigeria using Vertical Electrical Sounding (VES). Schlumberger configuration was used to delineate the hydrological structure of the subsurface of the study area. Thirteen VES stations were sounded within the study area and the data obtained were interpreted using computer iteration modelling (IPI2WIN) software program. The interpreted data show three layers which are topsoil, weathered basement, and poorly fractured basement.

Olateju O *et al.* (2017) Conducted resistivity survey in Awa-Iaporu, near Ago Iwoye southwestern Nigeria with the aim of delineating probable areas of high groundwater potential. The geophysical investigation involves the very low frequency electromagnetic (VLF-EM) and Vertical Electrical Sounding (VES) methods. The VLF-EM survey was at 10 m interval along eight traverses ranging between 290 and 700 m in length using ABEM WADI VLF-EM unit. The VLF-EM survey was used to delineate areas with conductive/fractured zones. Twenty-three VES surveys were carried out with the

use of Campus Ohmega resistivity meter at different locations. The VES results showed 3–4 geoelectric layers inferred as sandy topsoil, sandy clay, clayey and fractured/fresh basement.

Alabi *et al.* (2010), Conducted a resistivity survey study groundwater potential in Lagos State University (Faculty of Law open field), such as depth, thickness, resistivity, and sediment at which water can be obtained. The geo-electrical methods used in the survey are Vertical Electrical Sounding and Horizontal profiling, with the aim of determining which method is best used to determine groundwater potential. Four Vertical Electrical Soundings were conducted using the Schlumberger configuration and Horizontal spread covering the entire area. The VES data were subjected to an iteration software (WIN RESIST) which showed that the area is composed of topsoil, clay, sandy clay, and sand.

The general prevalence and stability in time and space of groundwater makes it a reliable and widely accessible resource, easily amenable to private, local, and on demand exploitation. However, this “common pool” property of groundwater also complicates a more formalized and coordinated control (Custodio, 2002). Therefore, strategies for significant improvements in groundwater supply are in the areas of formulation of adequate, efficient, and effective water policies, funding/ appropriate infrastructures as well as monitoring and evaluation.

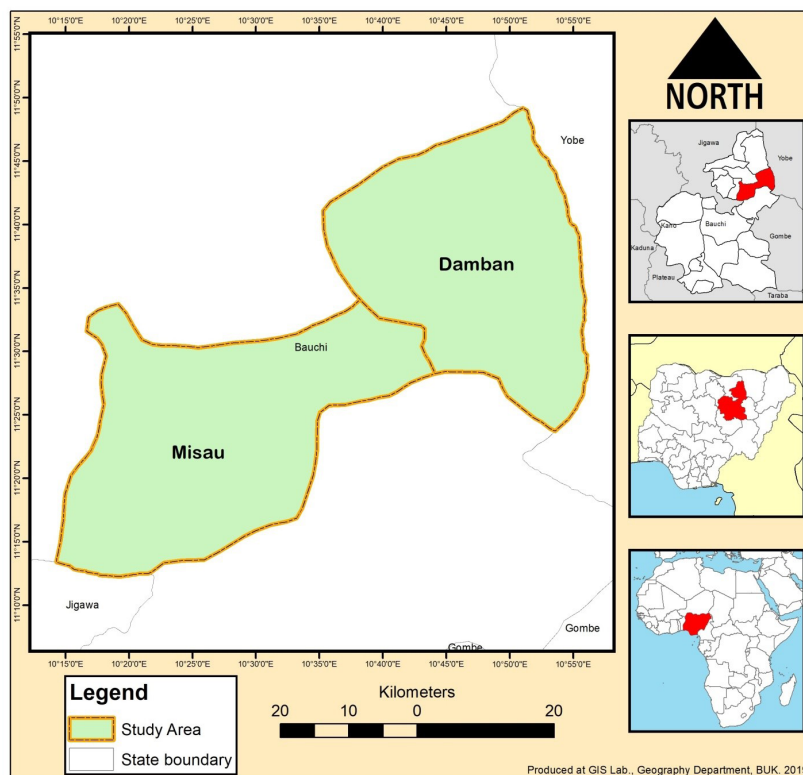
## MATERIALS AND METHODS

### Study Area

The study covered two local governments, Misau and

Dambam areas, and thirteen (13) points were surveyed, and are only within Misau and Dambam Local Governments, specifically the two geological characteristics of the study area one of coarse pophyticbiotitehomblende granite is more dominant in Dambam while sandstone shale and clay dominated the greater part of Misau. The study area, Misau, and Dambam are located between Latitude 11°13'31" and 11°50'21" N and Longitude 10°08'22" and 10°13'31" E. Misau local government area has an area of 1,226 km<sup>2</sup> and Dambam Local government area has an area of 1,077 km<sup>2</sup> (Wali *et al.*, 2015). The total land area for the two local government areas is estimated to be 2,327 km<sup>2</sup>. The local government was once inhabited by Hausa people before being seized in 1827 by the muslim rulers of Bauchi and Katagum, Yakubu and Dan Kauwa. Following their disagreement, the Sultan of Sokoto entrusted the town and its environs to Mamman Manga in 1831 (Yusuf, 2022).

Misau has a population of 420,262 while Dambam has a population of 240,762 people projected from the 2006 National census (NPC, 2006). The major land use in the area is farming in both rainy and dry seasons and cattle rearing. The climate in the study areas is that of the Sahel type, with two distinct seasons, the wet season is fairly short starting from May-September while the dry season, is wider from October-April. Mean annual rainfall is 800 mm with a unimodal distribution during the rainy season. The sunny duration mostly ranges from 5.1 to about 8.9 hours in July and November respectively. Moreover, October to February was found to be the longest sunshine hours.



**Figure 2:** Map of the Study Area

Source: Adopted from the Administrative map of Bauchi state

The amount of radiation is relatively constant throughout the year, varying from 11.3mm in July to 18.7mm in April. Although it is typically between 16.1mm and 18.7mm in March, April, and May, it is relatively highest during these months. In a similar vein, evaporation in the state varies from 2.4mm in July and August to approximately 15.7mm in March, with January and April experiencing the highest evaporation rates (Peter, 2012). The study areas have a lake called Maladumba that is situated a little far away from the Local Government headquarters approximately 18km from the southwest and 2km away from a fishing community Shelon village, (Abdullahi and Ibrahim, 2008). The lake has a tributary, River Kuka which drains into the river, and River Kari which drains the river during high water accumulation which mostly occurs during heavy rain periods from August through September (Ayeni, 2007).

**METHODOLOGY**

Determination of groundwater potential zones in the area Tetramer ALLIED OHMEGA SAS 300, which stands for (Signal Averaging System) was used to perform geophysical investigation for direct field measurements using a Schlumberger array this method involves passing of electric current into the ground through two metal electrodes and potential drop will be measure between a second pair of electrodes place in between them. The potential electrodes were fixed while the current electrode separation increase symmetrically about the center of the spread, then the reading will display on the screen where it will be taken in a recording sheet, the current electrode will then move to further take the next reading up to the last point.

Coordinates were taken in the field using Geographical Positioning System (GPS) at every sample point which help aid in identifying groundwater potential zones map and aerial extent of each zone the study area, lineament, drainage density, geology, hydrogeology, soil, and vegetation were also be obtained and determine through an overlay of all the thematic layers as adopted from (Rilwanu, 2014).

Constant Head Permeability Test was used in testing the soil permeability where the process begins with compacting the soil samples in a metal container designed for permeability. The container is then attached to the equipment where two tanks suspended will be filled with water connected to the vacuum pump from the middle and graduated cylinder from the bottom the pump is then opened for a second and a record of h1 will be taken repeatedly where head h1 and final head h2 in stand-pipe are recorded, h1/h2 and log10 (h1/h2) are calculated and recorded. Data of the Vertical Electrical Sounding (VES) were analyzed using ipi2win software while electrical resistivity values were used to determine layer thickness, potential aquifers, or zones in the areas, and the K value is in build by the software.

The results for the resistivity measurements were interpreted and presented following the conventional classification of resistivity concerning groundwater occurrence. Achie law and standards of Grant and West (1965), recommend an area with low resistivity and high depth tends to possess an aquifer that has more potentiality while an area with high resistivity with low depth is an aquifer with less groundwater potential in the basement complex formation.

**Table 1:** Conventional Classification of Resistivity to Groundwater Occurrence

S/N	Resistivity (Ohm-m)	Depth (M)	Remark
3	Above 500 ohm-m	<10-20	Low
2	300-450	20-30	Moderate
1	30-300	30 and above	High

Source: Rilwanu (2014)

The weighted overlay method and Analytical Hierarchy Process was used to analyse drainage density, geology, hydrogeology, and soil and vegetation density. The factors were given weight concerning the groundwater potential zones, weighted overlay method as adopted from Goyel *et al.*, (2009) in Rilwanu (2016). Analyst Extension of ArcGIS was used to obtain groundwater potential zones map by overlaying all the thematic maps, and weighting of impute of each map concerning their importance.

**RESULTS AND DISCUSSION**

**Identification And Characterisation of Groundwater Potential Zones**

The study employed five (5) thematic maps to delineate the groundwater potential zones in the study area, these maps include Lineament, Drainage, Vegetation, Geology, and Soil. The maps were ranked and assigned weight based on their importance to groundwater occurrence. However,

these maps are the controlling factor for groundwater in several studies conducted for groundwater assessment. The data type used includes the Digital Elevation Model (DEM), a Geological map of the area. Also, the extracted layers are lineament, drainage, soil, and vegetation. This result is similar to that of Habibu (2019) in Yauri Kebbi state where lineament takes the highest ranking and he uses elevation instead of Vegetation. According to his result, drainage takes the highest with 0.25 followed by geology with a density of 0.22, soil and vegetation have a density of 0.18 and the least was lineament with a density of 0.17. The result is also contrary to the findings of (Olutoyin, 2014) in South West Nigeria where he uses nine thematic maps and employs only three classes in the analytical hierarchy of high, medium, and low the scope of the work, several maps employ the analysis required minimum of five classes to enable various location get involved according to the availability in the area.

**Table 2:** Weighting of all factors

Factors	Drainage	Lineament	Geology	Soil	Vegetation	Weight	%
Drainage	1	3	3	5	4	0.25	25
Lineament	1/3	1	3	5	5	0.17	17
Geology	1/3	1	1	3	5	0.22	22
Soil	1/5	1/3	1	1	3	0.18	18
Vegetation	1/9	1/5	1/3	1	1	0.18	18
<b>Total (%)</b>						<b>1</b>	<b>100</b>



**Figure 3:** Recording of VES results in Bada Koshi Dambam L.G.A

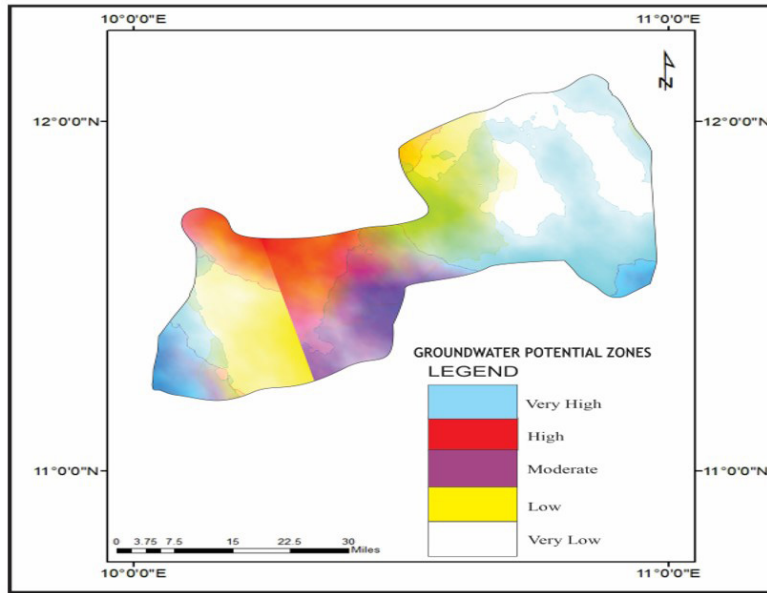
**Nature of the Groundwater Potential Areas**

The areal extents of groundwater potential zones were presented in (Table 3) According to the research findings, five groundwater potential zones were identified this include a very High groundwater potential zone out of the total area of 2096 km<sup>2</sup> 497 km<sup>2</sup>, which has the highest percentage of 25% followed by High groundwater potentials zone with 436 km<sup>2</sup> and 25% out the total area of 2096 km<sup>2</sup>. The third in the ranking of the zone is Moderate groundwater potential zones which cover 416 km<sup>2</sup> with 20% out of the total 2096 km<sup>2</sup> and Low groundwater potential areas covering 393km<sup>2</sup> 15% out of the total area of 2096 km<sup>2</sup> and the last groundwater

potential areas characterize to very cover 354 km<sup>2</sup> and 15% respectively. This result is in agreement with the findings of (Stanely, 2019) in Kogi State, Nigeria which reveals four groundwater potential zone namely Excellent, Good, Moderate, and Low groundwater potential zone, he used soil maps, geological and lineament density maps, vegetation maps produced from remote sensing images, drainage density, and vegetation maps to create a zone with potential for groundwater map using weighted overlay analysis. In addition, increased funding for urban planning is required, as is funding for the adaptation of strategies through urban planning and the strengthening of urban planning institutions. (Yusuf, *et al.*, 2023).

**Table 3:** Areal Extent of groundwater potential zones

S/N	Groundwater Potential Zones	Areal Extent In km <sup>2</sup>	Percentage %
1	Very Low	354 km <sup>2</sup>	15%
2	Low	393 km <sup>2</sup>	15%
3	Moderate	416 km <sup>2</sup>	20%
4	High	436 km <sup>2</sup>	25%
5	Very High	497 km <sup>2</sup>	25%
	<b>Total</b>	<b>2096 km<sup>2</sup></b>	<b>100%</b>

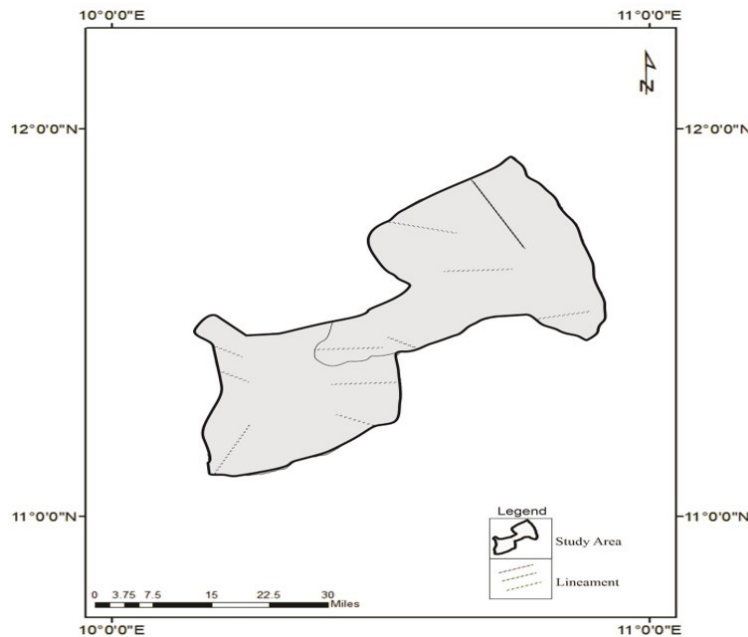


**Figure 4:** Recording of VES results in Bada Koshi Dambam L.G.A

**Lineament**

The fracture found within basement rock that facilitates the accumulation of groundwater abundance in a given aquifer is referred to as lineament. The findings revealed that areas with high lineament of 26-35km which include Rigar kari, Sebore Tohu, Gundari Makwalla, Zadawa Kinchi, Kukadi have more groundwater potential, while places under 16-25km which include Hardawa Fawari, Jalam Kukadi, and Dambam Bayan Tasha are of medium and the remaining Yanda Baladuwai, Janda Bada Koshi, Yame Bayan Primary, and Dambam A were found to

be under 1-15km. The findings further reveal that the lineament of the study area is in line with the result of the VES survey conducted for the study as well as the soil analysis of porosity and permeability however it's evident that places located in Misau reveals to have more lineament than that of Dambam. This result is in line with the findings of (Stanely, 2019) in Kogi State, Nigeria which categorizes the coverage of lineament in the study area based on the density indicated in each location he reveals four categories based on a hierarchy which includes low, moderate, high, and very high.



**Figure 5:** Lineament Density for Misau and Dambam

**Drainage Density**

The study reveals the drainage density to be at the paramount of the ranking for groundwater potential in

the study area where it has the highest weight of 25%. The drainage density is among the most important factor controlling groundwater potential, as the result

of weighting. The result shows that areas with drainage densities of 354 to 393 km<sup>2</sup> and 393 to 416 km<sup>2</sup> are characterized as low in terms of groundwater potential while areas with drainage densities of 416 – 436 km<sup>2</sup> and 436 – 497 km<sup>2</sup> are characterized as areas with high groundwater potential (Table 3). The drainage density of

an area determined the level of runoff to occur in an area however areas with high drainage density are more likely to have insufficient groundwater due to high level of runoff which results in poor infiltration, (Olutoyin, 2014), thus infiltration plays a vital role in natural recharge of aquifer both confined and unconfined.

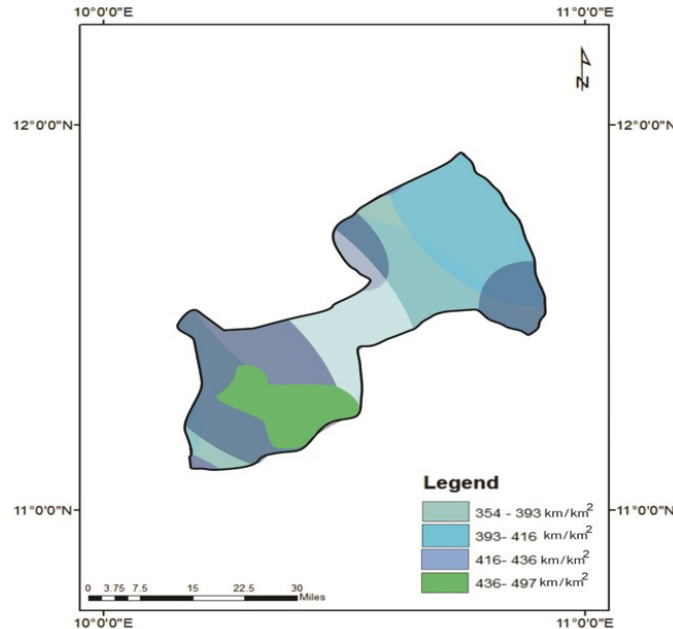


Figure 6: Drainage Densities of Misau and Dambam

**Vegetation**

The Sudan Savannah was determined to have a low groundwater occurrence, and this includes places like Bada Koshi, Dambam Bayan Tasha, and Bambam Bam. The study classified the vegetation type of the study area in terms of groundwater occurrence from high, average, to low. Due to the ability of some deep-rooted trees and other plants to use water from deep ground

level to nearly surface level, numerous scientific studies show a significant relationship between vegetation and groundwater occurrence in an area. According to Stanely (2019) in Kogi State where he stated that an area with high vegetation cover and waterlogged areas are good areas for groundwater infiltration, whereas in the case of Misau and Dambam the nature of vegetation is poor that alone can influence the recharge of groundwater in the area.

Table 4: Ranking and Weighting of Vegetation

Rank	Vegetation	Rank	Weight	Percentage %
1	Sudan Savannah	1	0.250	25
2	Grass Land	2	0.300	30
3	Sahel Savannah	3	0.450	45

**Geology**

Both the sedimentary complex formation in Dambam Local Government Area and the basement complex formation in Misau Local Government Area are present in the study area. The Kerri-Kerri sands and gravels to the west and the weathered and fractured basement (granite) predominating to the east are the two main aquifers on

which the study area is also developed. A thickened Kerri-Kerri sequence is developed in an East-West depression in the Basement complex. The Kerri-Kerri forms better aquifers than the basement complex in terms of yield and its aquifers are more developed for groundwater, being characterized by high transmissivities and hydraulic conductivities, as well as large specific gravity.

Table 5: Ranking and Weighing of Geology

Rank	Vegetation	Rank	Weight	Percentage %
1	Sandstone, Shale, and Clay	1	0.300	35
2	Biotite Granite	2	0.250	25

3	Horn blended Granite	3	0.350	40
	<b>Total</b>		<b>100</b>	<b>100</b>

**Soil**

Three main soil types, which were adapted from FAO soil classifications, predominated in the study areas. The Fadama loam, a latosol, was given a weight of 25%, the Sand clay, a loam/clayey soil, was also given a weight of 25% due to its contribution to groundwater occurrence, and the Sand Silt, which contains fine coarse element and is dark brown ferruginous, was assigned a weight of 50%. The sand silt is predominant in part of both Misau

and Dambam which comprises Yame Community, Jalam Community, Ajili Community, Gundari, and Kukadi of Misau inner town, while the fadama loam predominated some communities in Dambam which include Bam Community of Dambam A, and the main Dambam town. However, the sand clay is more predominant in communities that at the edge of Misau town which comprises places like Zindi Community, Makaurachi of Sirko Community, and Tohu of Sebare Community.

**Table 6:** Soil Ranking and Weighing

Rank	Soil	Rank	Weight	Percentage %
1	Fadama Loam	1	0.250	25
2	Sand Silt	3	0.500	50
3	Sand Clay	2	0.250	25
	<b>Total</b>		<b>100</b>	<b>100</b>



**Figure 7:** Recording Soil Sample weight in Civil Engineering Soil Mechanics Laboratory ATBU Bauchi

The permeability test shows that the drainage characteristics of Ajili, Gundari, Hardawa, and Sebare are poor, whereas those of Kukadi, Sirko, and Zadawa are good. The porosity ranges from 16.7% to 26.7% out of the total volume of 28m of the material. The drainage characteristics of Jalam, Dambam, Yanda, Yame, Dambam A, and Janda are poor. The results also revealed that the permeability of Ajili, Gundari, Hardawa, Sebare, Kukadi, and Sirko is low, only that of Zadawa was of the medium in nature, and that of Jalam, Dambam, Yanda, Yame, Dambam A, and Janda are very low. The entire soil sample possesses the same soil type of fissured and weathered clay& very fine or silty sands.

Thirteen (13) locations in Misau and Dambam each underwent a geophysical investigation. To identify the presence of about three to four geologic layers in the

study area, geo-electric sections of various profiles were derived using vertical electrical sounding, of which the topsoil, weathered rock, weathered/fractured rock, fractured basement, and fresh basement rock are composed. The VES Curves for Gundari Misau, Ajili Bakin Primary, Sirko Makaurachi, and Rigat Kari were found to be quite promising aquifers while that of Hardawa PHC indicates that the area is less promising in terms of potentiality when it comes to groundwater occurrence due to the presence of fractured basement in third layer with a resistivity of 964.7 (ohm).

The VES Curves for Zadawa Unguwan Galadima show that the area is non-promising due to the presence of weathered rock in a second layer with a resistivity of 13.7 (ohm), and drastic increase upto 372 (ohm), in the third layer lastly in Misau Sebare Tohu, the aquifer is highly

productive due to the presence of weathered basement in the second layer with a resistivity of 266.4 (ohm), and weathered laterite in third layer with a resistivity of 38.14(ohm).

## CONCLUSION

The study found that eight of the VES points show three geoelectric layers while four geoelectric layers were found in the remaining five VES points. The study further concludes that the general groundwater potential is good with the exception of five VES point which includes Hardawa and Zadawa of Misau and Bada Koshi, Bam, and Baladuwai of Dambam this is because of some lithological features of the area coupled with evidence of a drastic decrease in resistivity due to low thickness of the area. Five groundwater potential zones were identified, and they are very high, high, moderate, low, and very low groundwater potential zones. Among all the five groundwater controlling factors drainage proves to be the most important in assessing groundwater potentials in the area followed by geology, soil, and vegetation. The analysis of the type of water supply, the analysis of aquifer parameters such as permeability and porosity, and groundwater geophysical investigation are all conventional methods that can be used to thoroughly investigate groundwater potential areas.

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